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XI.

CONTRIBUTIONS FROM THE PHYSICAL LABORATORY OF
HARVARD COLLEGE.NO. XIV.—ON A NEW METHOD OF COMPARING THE ELECTRO-
MOTIVE FORCES OF TWO BATTERIES AND MEASURING
THEIR INTERNAL RESISTANCE.

BY B. O. PEIRCE, JR.

Presented, March 14, 1877.

THE relative strengths of two currents which give rise to different deflections of a galvanometer needle are not easily compared, and therefore it has been the aim of physicists in making electric measurements to choose such methods as require the current through the galvanometer to be made either zero, or else equal in two given cases. The method of measuring resistances by Wheatstone's Bridge is an example of a "nul" method. Mance's and Thomson's methods of measuring the resistances of batteries are examples of the class which require equal deflections.

Poggendorff's method of comparing the electromotive forces of two batteries is the only accurate method which belongs under either of these heads.

I have found that very accurate results can be obtained in the following way:—

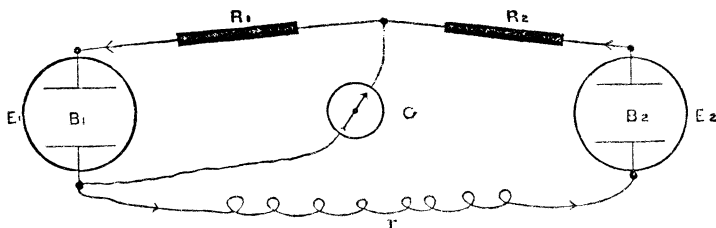


Fig. 1.

The batteries to be measured are arranged as in the figure, with their electromotive forces conspiring. r is any small resistance. R_1

and R_2 are resistances which may be varied until no current passes through the galvanometer. When the current through the galvanometer is nothing, the ratio of the electromotive forces of the two batteries is very easily found. Let E_1 and E_2 be the electromotive forces of the two batteries, and B_1 and B_2 their internal resistances.

Kirchoff's Second Law, when applied to the closed figure embracing the resistance B_1 , R_1 , G , gives,

$$E_1 = (B_1 + R_1)C \quad (1)$$

where C is the current traversing the circuit.

The same law when applied to the closed figure r , B_2 , R_2 , G , gives

$$E_2 = (r + B_2 + R_2)C \quad (2)$$

Dividing (1) by (2)

$$\frac{E_1}{E_2} = \frac{B_1 + R_1}{r + B_2 + R_2} \quad (3)$$

In order to use this formula, we must know the values of B_1 and B_2 . These may be determined thus: Give to R_2 a little different value, and vary R_1 until there is again no current going through the galvanometer. Repeat this operation with still a different value of R_2 , and there will be three different values of the ratio of the electromotive forces, which will give three equations to determine B_1 , B_2 , and $\frac{E_1}{E_2}$. R_1 and R_2 are most conveniently made large; and in this case, if extreme accuracy is not needed, we may neglect B_1 and B_2 compared with R_1 and R_2 .

It is, of course, not necessary to have any resistance corresponding to r ; but as it is often possible to get quite accurate results by making R_1 and R_2 small resistances, and then varying r by means of a rheostat until no current traverses the galvanometer, a resistance r is inserted in the figure.

The chief advantages of this method are:—

- 1st, its great accuracy.
- 2d, that the current through the galvanometer is made zero.
- 3d, that the circuit does not have to be broken during the comparison.
- 4th, that the resistances of the two batteries are very readily obtained without altering any of the adjustments, if their electromotive forces are constant.

The greatest disadvantage in this arrangement is that a large

current passes through the resistance coils. The current through the coils may be reduced by connecting, through a shunt, the battery-poles which are already connected by the resistance coils, and in this way one can avoid all risk of injuriously heating the fine wire.

The use of the shunt makes the formula which determines the ratio of the electromotive force of the two batteries a little more complex, but the mechanical work of the comparison is not altered.

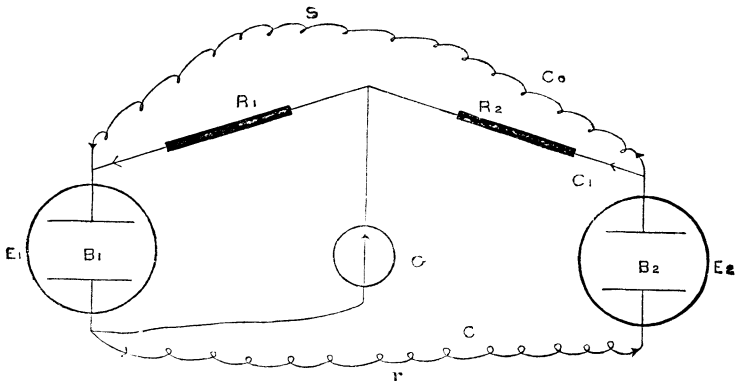


Fig. 2.

C (Fig. 2) is the strength of the current going through the undivided circuit. C_0 and C_1 are the strengths of the currents going through the shunt and through the resistance box respectively. Let S be the resistance of the shunt,

$$C = C_1 + C_0 \quad \text{and} \quad C_1(R_1 + R_2) = C_0 \cdot S$$

$$\therefore C = C_1 \frac{S + R_1 + R_2}{S}$$

$$C_1 = \frac{CS}{S + R_1 + R_2}$$

Kirchoff's Second Law gives, when applied to the closed figures B_1 , R_1 , and G , and r , B_2 , R_2 , and G ,

$$E_1 = B_1 C + \frac{R_1 SC}{S + R_1 + R_2} \quad (1)$$

$$E_2 = (r + B_2) C + \frac{R_2 SC}{S + R_1 + R_2} \quad (2)$$

Dividing (1) by (2)

$$\frac{E_1}{E_2} = \frac{B_1(S + R_1 + R_2) + R_1 S}{(r + B_2)(S + R_1 + R_2) + R_2 S} \quad (3)$$

which is the formula required.

NO. XV.—ON A NEW METHOD OF MEASURING THE RESISTANCE OF A GALVANIC BATTERY.

By B. O. PEIRCE, JR.

Presented, March 14, 1877.

OF the many known methods of measuring the resistance of a galvanic battery, only two, those of Mance and Thomson, are found to give accurate results. A third method, which seems to work well in practice, is this:—

A known resistance (r), a galvanometer of known resistance (G), and the battery whose resistance is to be measured, are joined up in a simple circuit. The battery is shunted, and the deflection of the galvanometer needle is noted. This shunt is now removed, and the galvanometer is shunted, so that it gives the same deflection as before. A knowledge of the ratio of the resistances of the shunts gives the resistance of the battery by means of a simple formula. Let E be the electromotive force of the battery, and B its resistance, and let S and σ be the resistances of the shunts. In the expressions that follow, C_g , C_s , and C_σ denote currents passing through the galvanometer and the two shunts respectively.

When the battery is shunted, the whole current in the circuit is

$$C = \frac{E}{\frac{1}{\frac{1}{S} + \frac{1}{r + G}} + B} = \frac{E(S + r + G)}{S(r + G) + B(S + r + G)} \quad (1)$$

Kirchoff's Laws give

$$C = C_g + C_s \quad \text{and} \quad C_s \cdot S = C_g(r + G)$$

therefore

$$C = C_g \frac{(S + r + G)}{S} \quad (2)$$